Mars Drilling and Planetary Engineering Research

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Major Thrusts

- Mars subsurface exploration (drilling)
- Science instrumentation (LIBS-RAMAN)
- Planetary "civil engineering" problems; e.g., mining, habitat construction, *in situ* resource utilization

What We Do for NASA on Mars Drilling

1. Technology and subsurface exploration planning, roadmapping
2. Drilling systems analysis
3. Drilling/sampling technology development

1 Technology and subsurface exploration planning, roadmapping

System	System Science Objectives	Operational Objectives
Near-Surface Explorer (1–20 m)	• characterize near-surface materials (cuttings samples—min/pet, geochem) • geophysical sensing of subsurface (seismic array, GPR, gravity)	• multiple sites, short-range rover • return to base for sample analysis and recharge • remote control & mobility demonstration
Shallow Subsurface Explorer (200 m)	• characterization of shallow subsurface (core samples) • expanded geophysical sensing (heat flow array)	• point landing at one of surface sites • demo partial autonomous drilling • demonstrate core sample handling
Deep Hydrosphere Explorer (4000 m)	• sample deep hydrosphere • search for biosphere • expanded core analysis • expanded geophysical sensing • validate geophysical models with samples	• point landing at shallow site • demonstrate autonomous deep sampling
Water Production (4000 m)	• produce water & other resources	• demonstrate production well completion & operation (5-cm-diam.) • demonstrate resource handling/storage

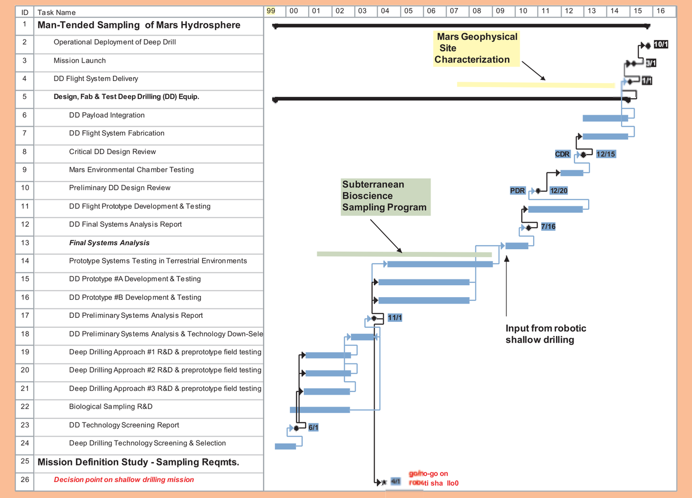
Technology Drivers

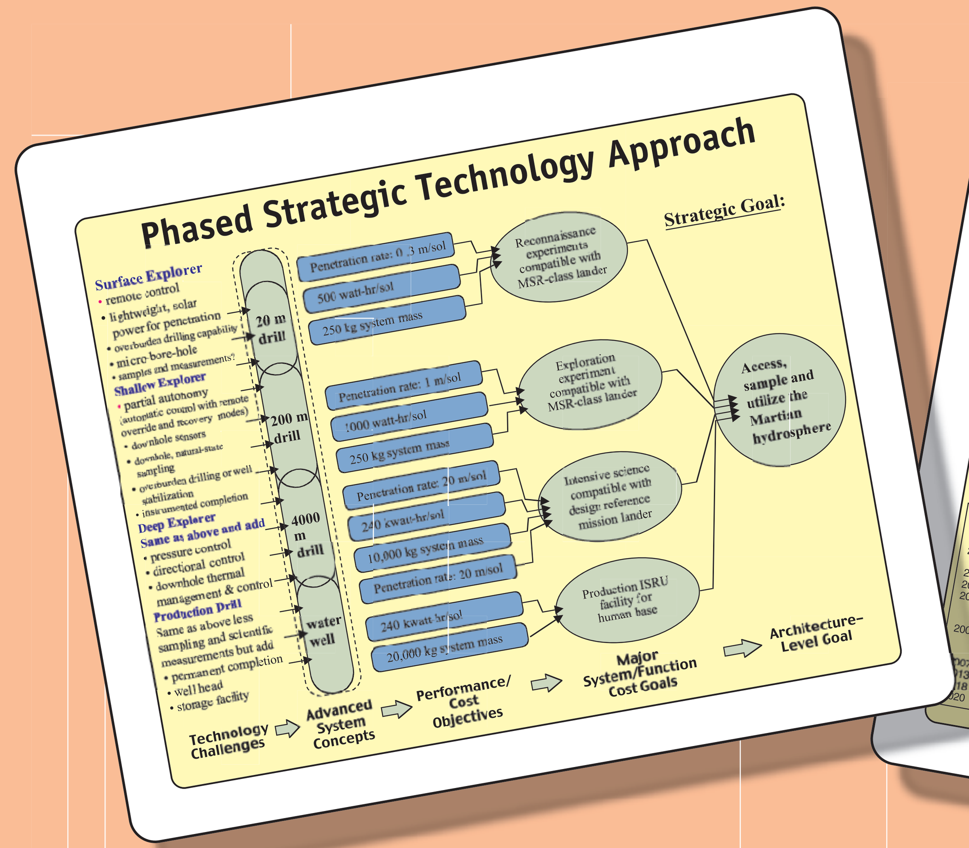
➨ NASA Mars exploration planning
- Robotic precursors: 2007–2015
- Manned landings: 2011–2015?

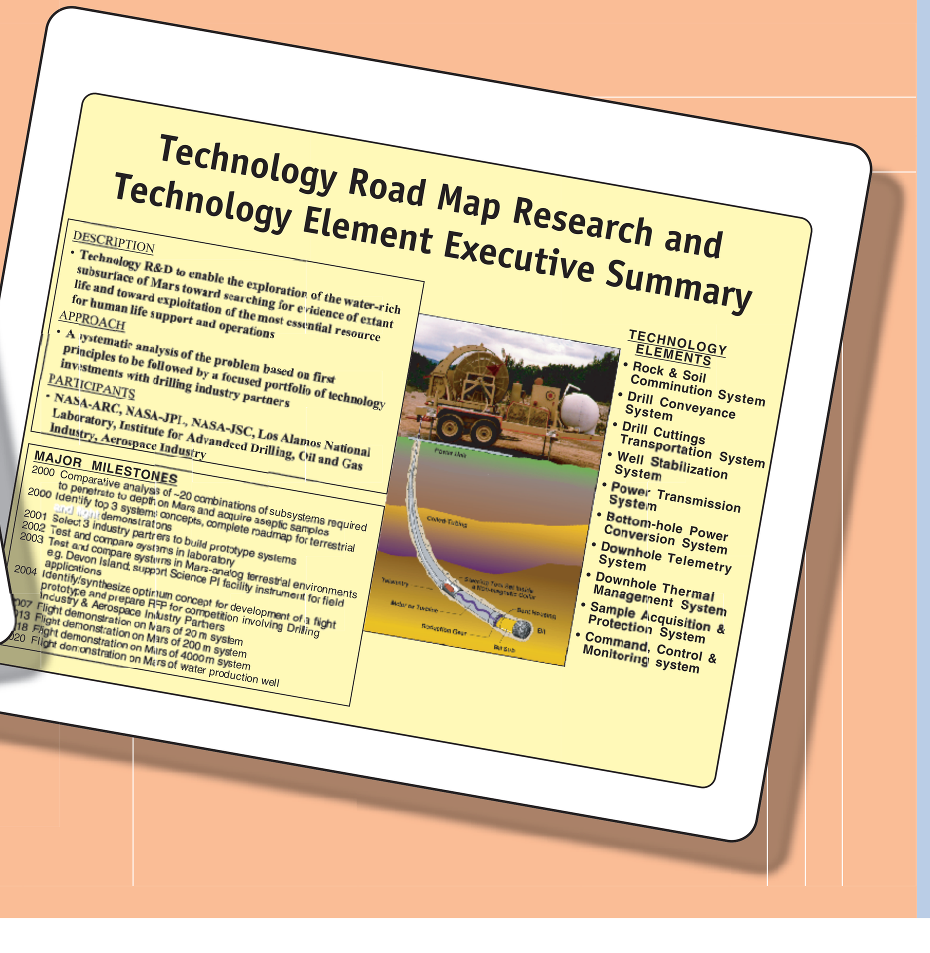
➨ Biosampling constraints
- Forward/backward/cross contamination
- Natural state sampling

➨ Martian environment

➨ Drilling—the ultimate wildcat
- All geophysical data unverified by drill bit







2 Drilling systems analysis

Report on a Conceptual Systems Analysis of Systems for 200-m-Deep Sampling of the Martian Subsurface

J. Blacic, D. Dreesen and T. Mockler

November 8, 2000

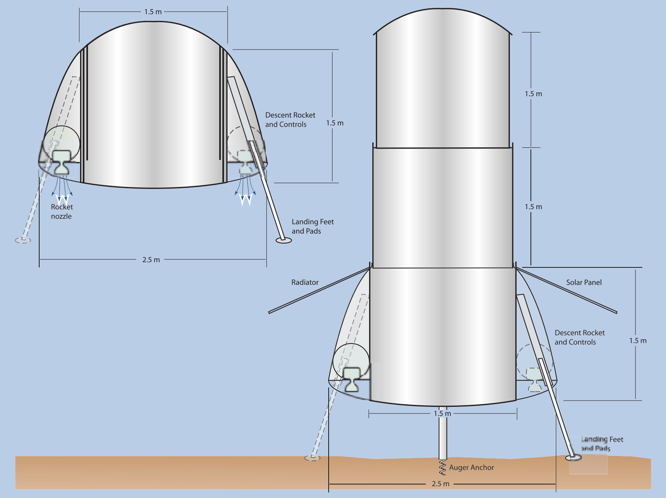
LAUR 00-4742

Los Alamos NATIONAL LABORATORY

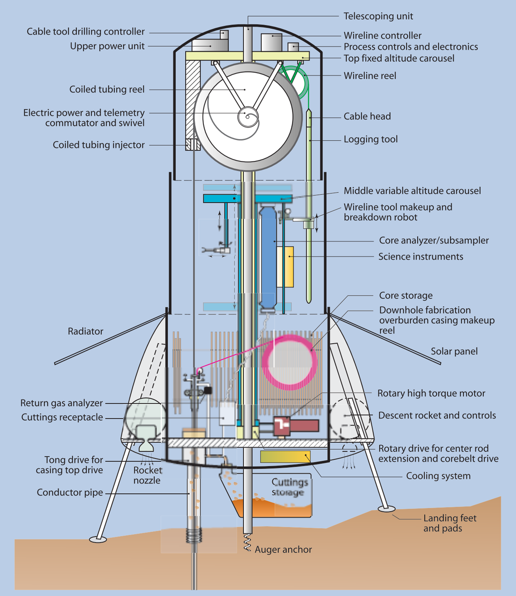
http://www.ees4.lanl.gov/mars/

Example Systems

System envelope



System I



Shallow Sampling Conceptual Systems Analysis

➨ Assumed mixed rock penetration required
- Basalt flows, well-cemented to non-consolidated sediments, impact crater debris, ground ice/clathrates—hole stability conditions unknown but no pressurized fluids expected

➨ On-site analysis of samples, no return; measurements while drilling

➨ Leave instrumented hole

➨ 36 possible systems identified

➨ Reduced to ~12 on first-order considerations

➨ More detailed analysis reduced systems to 3 example conceptual system descriptions

Study Objectives

➨ Mission definition
- Develop a concise statement of mission requirements, resources and constraints

➨ Impacts
- Determine how mission definition and environment affect drilling/sampling technologies

➨ Technology survey
- Identify proven drilling technologies that are potentially applicable to this mission

➨ System screening
- Of the possible technologies, which systems are most likely to meet the mission objectives?

➨ Conceptual design
- Identify 2 or 3 "best" systems and describe them

Fundamental Study Conclusion

➨ Only high-efficiency, mechanical, overburden-type drilling approaches are feasible for this mission with hole diameters of ~35 mm and core samples of ~15 mm in diameter which may have to be sub-sampled to meet contamination constraints

➨ No existing terrestrial systems can meet the mission requirements without substantial modification

3 Drilling/sampling technology development

Subsurface Sampling Concept for Mars 2007 Lander

J. Blacic, D. Dreesen and T. Mockler

February 27, 2001

LAUR 00-1272

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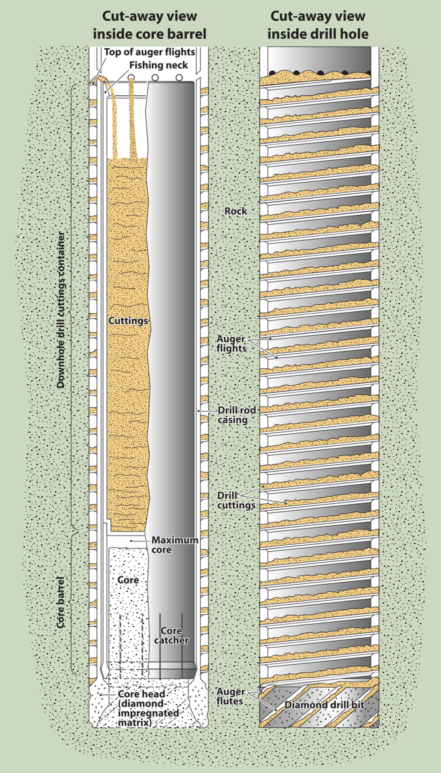
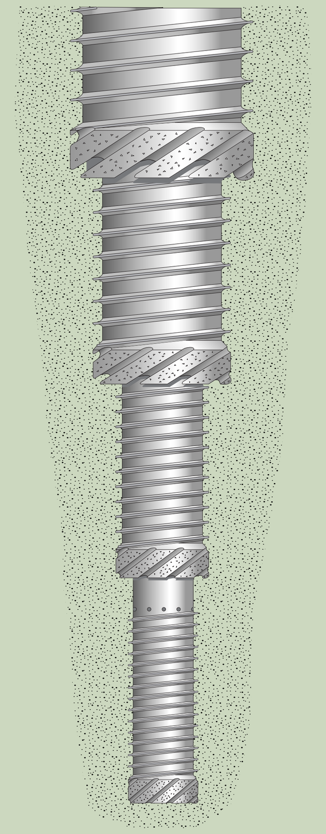


Mars 2007 Subsurface Sampling Concept

➨ Conservative, flexible approach capable of penetrating a wide variety of rock types and subsurface conditions

➨ Preserves thermal and compositional integrity of samples

➨ Meets mission power and mass constraints for all cases



Concept Features

➨ Hole stability provided by drilled-in casing at all depths

➨ Comminution by combined rotary-micropercussion drilling

➨ Cuttings removal by combined auger-sonification

➨ Samples in the form of fine-grained cuttings and continuous core

➨ Vertical, stabilized hole achieved by stepped diameter, concentric drill rod

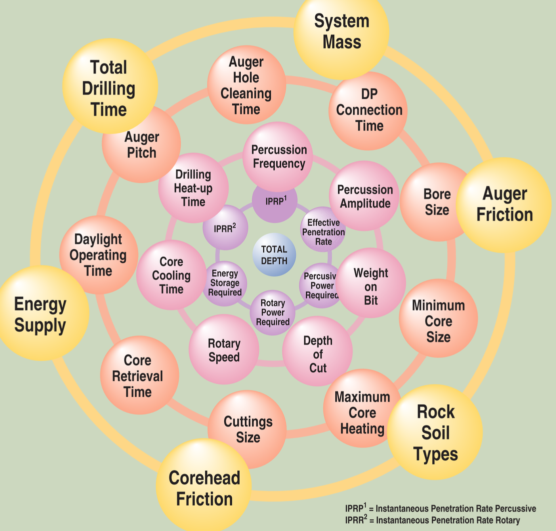
Drilling in the Mars Environment
Strengths of the Proposed System

➨ Very robust and flexible approach

➨ No tripping of drill stem required
- Drill rod connections will not occur after the rods are exposed to Martain dust and fine drill cuttings
- Hole cavings will not have to be redrilled
- Bore is never left unsupported

➨ Diamond core and auger drilling are mature drilling technologies
- Basic terrestrial mechanics are well understood
- Optimization for Mars can begin as soon as laboratory data are available and system requirements are specified

➨ System produces core and fine cuttings for analysis with minimal contamination



Feasibility Assessed through Drilling Physics Numerical Model

➨ Diamond drag bit physics submodel calculates kerfing energy

➨ Auger and buckling submodels characterize cutting removal and drill rod stability

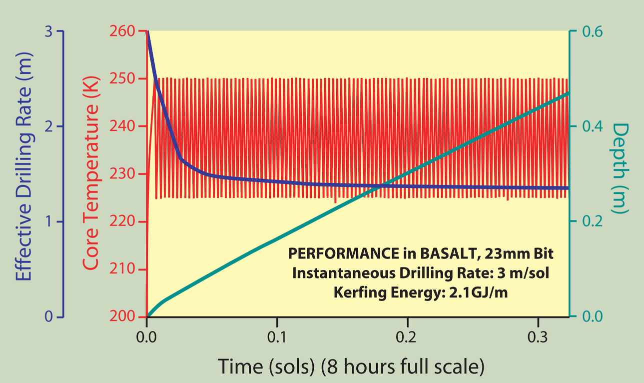
➨ Thermal submodel calculates sample heating due to generation and transport of process energy

➨ Limiting sample heat-up determines power and effective advance rate

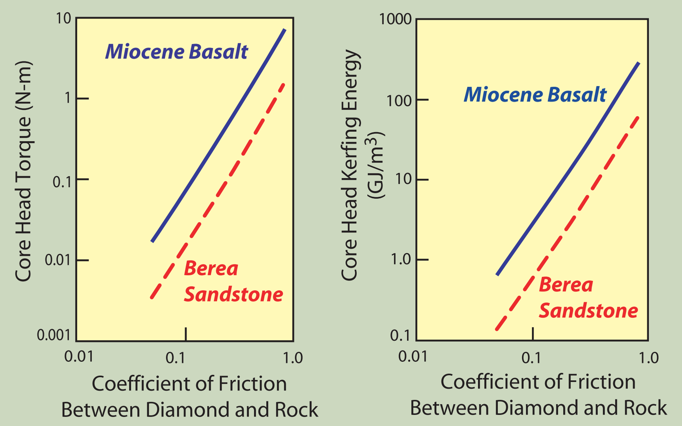
➨ Power limits maximum and minimum instantaneous advance rate

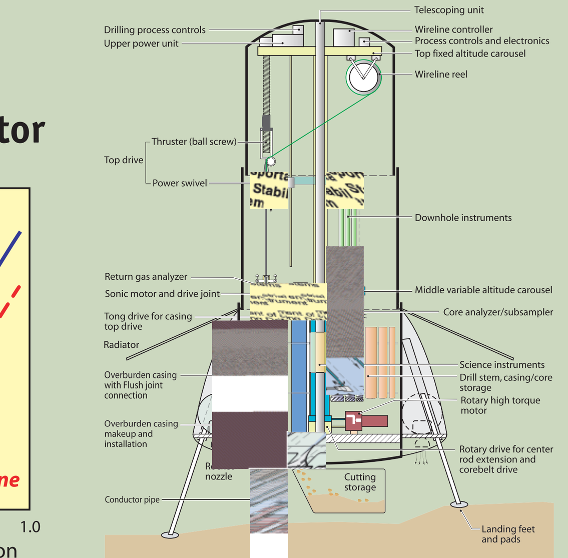
➨ System mass and/or power determine maximum depth

Sample Heating Controls Effective Advance Rate



Rock Type can be a Significant Factor





Concept Summary (for 25-m depth)

Casing (mm)	14.3	21.5	32.3	48.5	72.8
String length	25	16	9	4	1
Daytime energy	94	96	149	194	202
Masses:					
Drill system	5.4	12	22	36.5	64.7
Wireline	1.2	1.6	2.3	4	7.8
Surface system	17.7	24.3	31.9	44.9	70
Total mass	24	38	56	85	143
Drill time (Sol)	38	48	52	57	61